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Evolution of Titan's atmospheric temperature and composition near the poles from Cassini/CIRS

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Abstract

We will report on the monitoring of seasonal evolution near Titan's poles. Since 2010, we have observed at Titan's south pole a strong temperature decrease and the onset of a dramatic enhancement of several trace species such as complex hydrocarbons and nitriles (HC3N and C6H6 in particular) previously observed only at high northern latitudes (Coustenis et al. 2016 and references therein). This is due to the transition of Titan's seasons from northern winter in 2002 to summer in 2017 and, at the same time, the advent of winter in the south pole. During this transition period species with longer chemical lifetimes linger in the north undergoing slow photochemical destruction, while those with shorter lifetimes decrease and reappear in the south. An opposite effect was expected in the north, but not observed with certainty until now. We present here an analysis of nadir spectra acquired by Cassini/CIRS (Jennings et al., 2017) at high resolution in the past years and describe the temperature and composition variations near Titan's poles. From 2013 until 2016, the northern polar region has shown a temperature increase of 10 K, while the south has shown a more significant decrease (up to 25 K) in a similar period of time. While the south polar region is continuously enhanced since about 2012, the chemical content in the north is finally showing a clear depletion for most molecules only since 2015 (Coustenis et al., 2017, submitted for publication). This can set constraints on photochemical and GCM models.

1. Observations and analysis

For the purpose of this article, we exploited CIRS high spectral resolution (0.5 cm-1) data taken from 2012 to 2016 in the surface-intercepting nadir mode. CIRS is a Fourier transform spectrometer spanning 10 to 1500 cm-1 in three spectral channels or Focal Planes (FP). We use here spectra from the far-infrared FP3 and FP4 that cover the 600-1500 cm-1 range (Jennings et al. 2017).

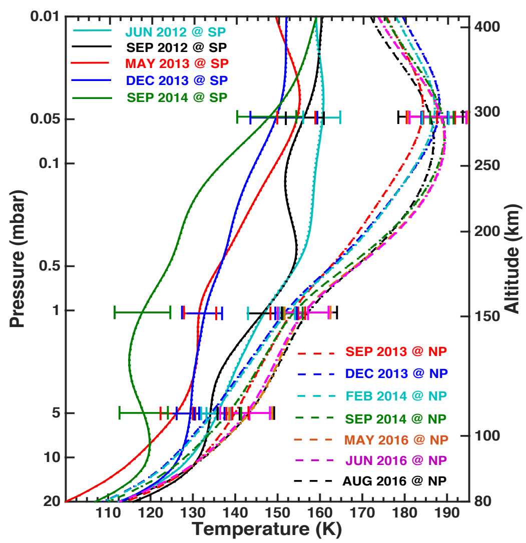

Fig. 1. Temperature evolution in Titan's stratosphere near the poles from 2012 to 2016. The southern polar profiles are shown in full lines, while the north pole profiles are depicted in dashed lines and the different dates are indicated in different colors. 3-σ uncertainties are shown.

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2. Results

In our recent publications (Coustenis et al. 2016; 2018), we inferred the temperature profiles and the chemical composition at different dates from 2010 and up to 2014 for high northern and southern latitudes (at and beyond 50°N and 50°S).

We derive the temperature profile from the methane n4 band and then apply the ARTT code to the rest of the spectrum to extract the abundances of the weak gases.

We had already shown in Coustenis et al. (2016) that as the southern hemisphere moved into winter after 2010, large temperature variations were observed near the south pole (70°S) in the stratosphere (from 0.1 down to 1 mbar pressure levels). Indeed, while a moderate warming is observed in the summer-entering north for the mid and high northern latitudes, a decrease of about 10-15 K in temperature was measured already for the 50°S latitudes. A more spectacular drop in temperature by as much as 25 K at 70°S was measured from 2012 to 2014. These temperature variations were accompanied by a strong enhancement of chemical compounds in the south polar region, while the north failed to show the opposite effect, which indicated a non-symmetrical reaction to the seasonal influence for each pole. We explore here more recent dates seeking to determine longer-term seasonal effects near Titan's poles.

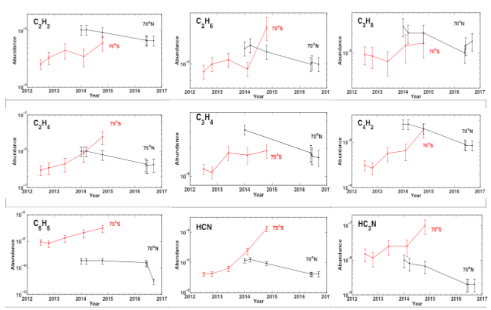

Fig. 2. Retrieved abundances of trace gases above Titan's poles.

More recent data now focusing at the poles : our radiative transfer results at high Northern latitudes (at about 20° from the pole), show that the North pole is now becoming significantly depleted in trace gases. This occurs essentially after 2015. Not much difference again is found for CO2 (not shown in this figure). Limited drop in mixing ratios within error bars is measured for the other most abundant molecules resisting the photolysis (like C3H8, C2H6, C2H2 or C2H4). However, the trend for a drop in content for these molecules is attested by the consistent lower values found for these species in all 2016 spectral averages wrt 2014.

References

[1] Coustenis et al., 2016, Icarus 270, 409-420

[2] Jennings et al., 2017, Applied Optics 56, no 18, 5274-5294.

[3] Coustenis et al. 2018. Astroph. J., Lett., 854, no2